Edge Bead Control Method and Apparatus

Field of the Invention

The present invention is related to the field of microfabrication. In particular, the present invention is related to methods for using and handling wafers.

Background

Several microfabrication processes call for the use of very thick layers of photoresist. Typically, photoresist layers are applied to wafers by a spinning process. An amount of photoresist is applied in liquid form to a wafer, and the wafer is spun at a predetermined speed for some period of time to spread the photoresist across the wafer surface. A common problem for thick layers is the formation of an edge bead, which is a marked increase in thickness near the outer edge of the wafer. Significant variation in the photoresist thickness creates problems in exposure and development of photoresist during lithography as well as variations in finished die characteristics across a given wafer. In particular, when using a contact mask, a large edge bead can prevent direct contact across a significant area of the wafer, reducing resolution in lithography.

Figure 1 shows a graphical representation of the edge thickness for three inch and four inch wafers on which a very thick layer has been spun in a prior art process. The dashed lines indicate illustrative upper and lower acceptable bounds for the photoresist layers. The acceptable bounds may vary widely from one process to another. The useful area 10 for the four inch wafer has a diameter of about 2.375 inches, while the useful area 12 for the three inch wafer has a diameter of about 1.5 inches. Approximating the useful areas 10, 20 as circular, the percentage of the four inch wafer area that is useful area 10 is about 35%, while the percentage of the three inch wafer area that is useful area 20 is

about 25%. A further problem is that a limiting factor on edge bead size is the centrifugal force on the photoresist during spinning; for small wafers, the centrifugal forces generated are reduced by reduced radius of the wafer edge versus a larger wafer. These low percentages reduce chip yield from each individual wafer, increasing production costs by any of several measures, including wasted goods, environmental harm, and extra time in terms of machine usage and personnel hours.

In several processes, including, for example, a number of vertical cavity surface emitting laser (VCSEL) fabrication processes, thinned wafers are used. For example, rather than using a typical 500 micron thick wafer, some processes use wafers that are about 300 microns thick. These thinned wafers tend to be fragile. Further, some specialized processes, including VCSEL fabrication, make use of special wafers that are relatively small in comparison to the large wafers that many new microfabrication process machines are made to process. While many Si wafer processes for integrated circuitry now use or are configured to use eight inch or larger wafers, specialty processes such as some research and development as well as VSCEL fabrication processes make use of three, four or six inch wafers.

Summary

The present invention, in an illustrative embodiment, includes an apparatus which aids in reducing the incidence and effects of an edge bead on the profile of a thick photoresist layer. A first illustrative embodiment includes a wafer holder designed to hold a wafer while photoresist spinning or other wafer processing steps are performed. The wafer holder may have a pocket shaped and designed to receive a wafer of a particular size. In a further embodiment, the wafer holder may be shaped such that it may

be received by wafer processing apparatuses and treated as if the combination wafer holder and wafer of a first size is a wafer of a different size from the first size. In yet another embodiment, the wafer may include an outer groove which aids in containing the spread of photoresist and in releasing a wafer from the holder.

Another illustrative embodiment includes a method of preparing a wafer for a processing step. The method may include providing a wafer holder adapted to receive the wafer. The method may further include placing the wafer in the holder, and then performing a process step such as, for example, spinning photoresist onto the wafer or other lithography and/or epitaxy or material deposition steps, etching steps, grinding, or the like. The method may also include securing the wafer in the holder by use of a mechanical device or by the application of a suction or vacuum force.

Yet another illustrative embodiment includes a method for reducing edge bead thickness during spinning of a photoresist layer. The method may include providing a wafer holder adapted to receive a wafer and hold the wafer during a photoresist spinning step. The method may also include configuring the wafer holder to receive a wafer of a first size and sizing the wafer holder to resemble a wafer of a second size that is larger than the first size.

Brief Description of the Drawings

Figure 1 is a graph representing the profile of a thick photoresist layer applied using a prior art process to different size wafers;

Figure 2 is an elevation view of a wafer holding apparatus in accordance with an illustrative embodiment of the present invention;

Figure 3 is a cross sectional view taken along line 3-3 of Figure 2;

Figure 4 is a cross sectional view of a working embodiment;

Figure 5 is a cross sectional view of the working embodiment from Figure 4 with a wafer inserted in the pocket and photoresist spun on the surface; and

Figure 6 is a graph representing the profile of a thick photoresist layer applied using a working embodiment of the present invention.

Detailed Description of Several Embodiments

The following detailed description should be read with reference to the drawings. The drawings, which are not necessarily to scale, depict illustrative embodiments and are not intended to limit the scope of the invention.

Figure 2 is an elevation view of a wafer holding apparatus in accordance with an illustrative embodiment of the present invention. The wafer holder 30 includes a recessed area or pocket 32. The pocket 32 includes a channel 34 which is fluidly connected to a number of vacuum holes 36. A raised outer portion 38 defines the pocket 32. In use, a wafer is placed into the pocket 32 and a vacuum force may be applied using the channel 34 and vacuum holes 36. The use of a channel 34 and vacuum holes 36 is merely illustrative of one of many ways a vacuum force may be used to secure a wafer into the pocket 32. The vacuum force/suction may include simply using a pressure which is reduced relative to the surrounding atmosphere and need not mean the application of some certain level of vacuum pressure. Additional channels may also be provided in various locations such as, for example, that illustrated in the working embodiment below.

In other embodiments, other wafer securing apparatuses or features may be used to replace the channel 34 and vacuum holes 36. For example, clips may be provided around the outside of the pocket 32. A wafer may have a hole or holes drilled in, and a

screw used to hold the wafer into the pocket 32. Pressure may be provided from the periphery of the pocket 32, for example, with a set screw extending through the raised outer portion 38. A tab or tabs may be provided along the periphery of the pocket 32 such that the wafer may be inserted with the primary or secondary flat aligned to pass by the tabs. The wafer can then be rotated, and pressure may be applied to at least one flat, allowing the tabs to hold the wafer while the flats assure a desired crystalline alignment.

For the illustrative embodiment, a receiving primary flat 40 is provided to define a part of the border of the pocket 32. An outer primary flat 42 is defined on an edge of the wafer holder 30 so the outer primary flat 42 aligns with the receiving primary flat 40. A wafer received in the pocket 32 can be treated by processing apparatuses designed for a larger wafer in a way that accounts for the crystalline orientation of the wafer.

While the wafer holding apparatus 30 of Figure 2 is illustrated having only a primary flat plane (corresponding to the structure of many types of wafers including, for example, a P-type (111) Si wafer), a secondary flat may be provided as needed for any wafer design. For example, using Si terminology to keep discussion simple and short, a wafer holding apparatus having a secondary flat at an angle of 45 degrees to the primary flat could be used for an n-type (111) wafer, an angle of 90 degrees for a p-type (100) wafer, or an angle of 135 degrees for an n-type (100) wafer. If desired, the flat may be omitted, for example, for additive or surface processes or where specific alignment of the crystalline orientation of the underlying wafer is not needed.

Figure 3 is a cross sectional view taken along line 3-3 of Figure 2. As illustrated in Figure 3, the pocket 32 includes a channel 34 as well as through holes 36. The pocket 32 has a height 44. The height 44 may be of any desired size. In one illustrative

embodiment, the height 44 is chosen to be equal to the thickness of a wafer that is to be held in the pocket 32. The height 44 may also be chosen to be greater or less than the wafer thickness. In another example, the height 44 is equal to the thickness of a wafer plus some fraction of the desired thickness of a photoresist layer to be deposited on the wafer.

The pocket 32 also has a width 46 which may correspond to the size of a wafer to be received by the pocket 32. The holder 30 may have an overall width 48 that is chosen to correspond to a known wafer size, although any appropriate size may be selected. In one example, the pocket 32 has a width 46 corresponding to a 3-inch wafer, and the holder 30 has a width 48 corresponding to the size of a 4-inch wafer. Other combinations may of course be used with 3, 4, 6, 8 or 12 inch wafers, for example, or any other size.

The holder 30 may be made of any material including a variety of metals, plastics, ceramics, glass, or crystalline materials. Some illustrative considerations in choosing the material for the holder may include the compatibility of the material with selected processes to be performed on a wafer held in the holder 30, cost of the material, or ability to form the material within desired tolerances. Some example compatibility considerations may include durability or strength, density/weight, melting or plastic deformation temperatures, adherence to photoresist, electrically insulative properties, or resistance to etching chemicals. In the working embodiment explained below, the illustrative holder was constructed of aluminum.

In several embodiments, the wafer holder 30 is used with devices that apply a suction through channels on a surface. For example, many conventional spinning apparatuses include channels and/or through holes which apply suction to wafers placed

on a rotatable surface. The through holes 36 may be placed, at least on the bottom of the holder 30, to correspond to a design of channels and/or holes on the rotatable surface of a spinning apparatus. The lower portion of the wafer holder 30 may also include channels or other designs that facilitate passage of vacuum force to the through holes 36. Often, once photoresist is applied on the wafer, the wafer will be held in place in part by the typically sticky photoresist after spinning is completed, and so when the vacuum force is removed the wafer stays in place.

In other uses, vacuum pressure may be applied to hold a wafer in place and the through holes 36 and/or the channel 34 may be plugged to maintain suction. The step of plugging the through holes 36 may be performed in a vacuum environment by dipping a portion of the back side of the holder into a semi-liquid material, or by placing a cap or other device over the back of the holder. A thin plastic adhesive layer (i.e. a specially designed tape) may also be applied.

By securing a wafer in a holder such as holder 30, the present invention may provide added safety in wafer processing. For example, many wafers are quite fragile and the use of a holder may improve durability during processing. Also, given the caustic chemicals often in use, a person working in a lab is often required to wear gloves, making the handling of a wafer difficult. The added bulk of the holder 30 makes handling easier. Further, in particular with thinned wafers, the wafers themselves tend to be brittle and the use of a holder may prevent accidental breakage during handling. In some embodiments, the use of suction applied to the back side of a wafer may also improve surface properties, in particular, reducing curvature caused by differences in the coefficient of thermal expansion of layers of a wafer.

Figure 4 is a cross sectional view of a working embodiment illustrating various features. The working embodiment holder 50 was constructed using aluminum. The holder 50 includes a pocket 52 having a depth 54 of 333 μm. Several through holes 56 are in fluid communication with several channels 58 defined in the bottom of the pocket 52. The pocket 52 has a width 60 of 3.005 inches (76.33 mm), while the holder 50 has a width 62 of 3.937 inches (100 mm). An extra circumferential groove 66 is included in the pocket 52. The groove 66 serves several purposes as noted below.

For the working embodiment, the holder 50 was used to illustrate an improved photoresist layer that is spun with a wafer in the holder 50. The result of this step is illustrated by Figure 5, which is a cross sectional view of the working embodiment from Figure 4 with a wafer inserted in the pocket and photoresist spun on the surface. A wafer 68 is placed in the pocket 52, and vacuum suction was applied by the spin apparatus through the through holes 56. There is a gap between the edge of the wafer 68 and the wall of the pocket 52 which allows for easier removal of the wafer 68 from the pocket 52, but which also allows some photoresist 70 to seep around the wafer 68. Then an amount of photoresist was placed on the wafer 68, and the wafer with the holder 50 was spun to spread the photoresist. It should be noted again that the figures are not necessarily to scale.

After spinning, a layer of photoresist 70 is deposited over the surface of the wafer 68 as well as the wafer holder 50. It can be seen that the edge bead of the photoresist 70 is actually over the wafer holder 50, and not the wafer 68 itself. Some of the photoresist 70 seeps beneath the wafer 68 into the groove 66. The groove 66 helps prevent any of the photoresist 70 from reaching the channel 58 and through hole 56. After a pre-bake of

the photoresist 70, and before exposure, the edge bead on the photoresist 70 is cleaned off with acetone, allowing for effective use of a contact mask for lithography. After exposure, the wafer holder 50, wafer 68 and photoresist 70 are subjected to development, during which an amount of alcohol or acetone (depending on what is used) seeps into the groove 66, dissolving and removing the photoresist 70. When placed on a hot-plate, the alcohol or acetone that seeped into the groove 66 boils and evaporates, expanding greatly, and causes the wafer 68 to pop out of the pocket 52, making the step of removing the wafer 68 from the pocket 52 very simple, easy and clean.

Figure 6 is a graph representing the profile of a thick photoresist layer applied using a working embodiment of the present invention. Again, the dashed lines illustrate acceptable bounds for the photoresist layer. The acceptable region 80 extends over a greater area of the wafer. The result of the working embodiment is that slightly more than 2 inches of the diameter of the three inch wafer is now usable, providing a yield of about 44% of the area of the wafer, nearly double that for the three inch wafer by itself as illustrated in Figure 1. Use of an even larger wafer holder relative to the wafer 68 may yield further improvement.

In an alternative embodiment, a wafer holding apparatus may be provided which lacks a pocket or recessed area for receiving a wafer. Instead, the wafer holding apparatus may include a number of channels and/or through holes which extend to a flat surface on which a wafer may be placed. A suction or vacuum force may then be applied using the through holes to secure the wafer in place on the holder.

Those skilled in the art will recognize that the present invention may be manifested in a variety of forms other than the specific embodiments described and

contemplated herein. Accordingly, departures in form and detail may be made without departing from the scope and spirit of the present invention as described in the appended claims.